



Inaugural Meeting of the Carbon Sequestration Leadership Forum

Session on Active Sequestration Projects

IEA Weyburn CO₂ Monitoring and Storage Project

**Presentation Based on Poster Material,
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Office of Energy Research and Development
Energy Sector, Natural Resources Canada**

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IEA Weyburn CO₂ Monitoring and Storage Project

Outline of Today's Presentation

- 1. EnCana's Weyburn Oil Field
A CO₂ Enhanced Oil Recovery (EOR) Project**
- 2. IEA Weyburn Monitoring and Storage Project**
- 3. Weyburn's Contribution to Advancing
Monitoring Technology**
- 4. A Model of International Technology
Collaboration**





1. EnCana's Weyburn Oil Field

A CO₂ Enhanced Oil Recovery Project



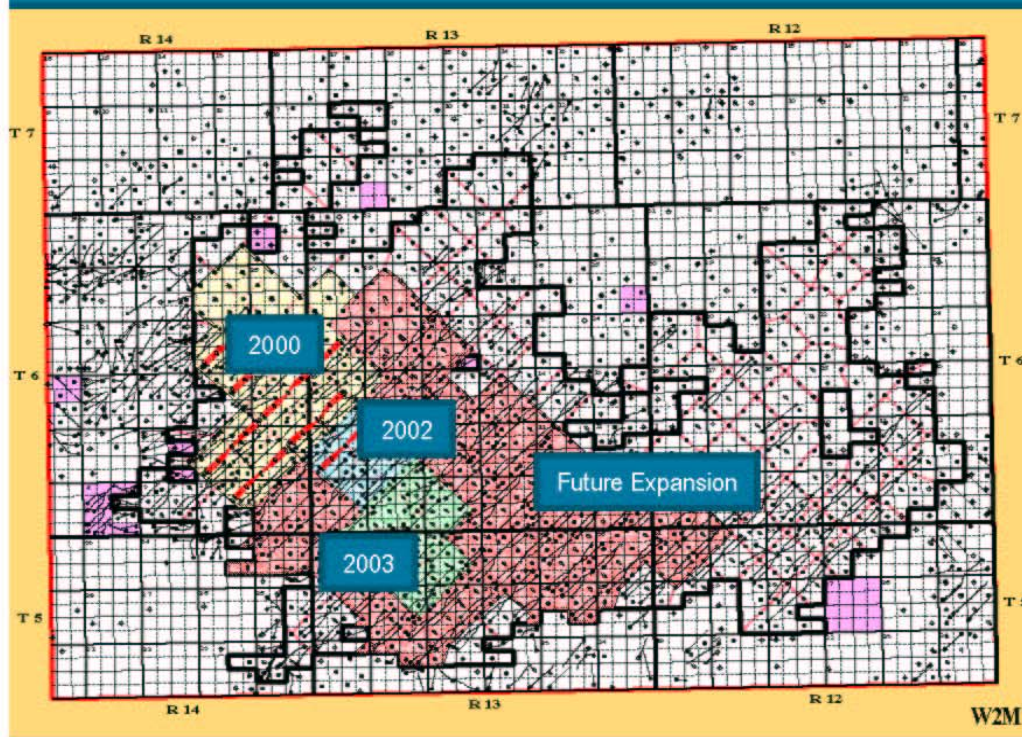
Weyburn Oil Field



Weyburn Unit: Field Size: 179 km²
Oil Recovered: 56 million m³

OOIP: 220 million m³
CO₂ IR: 20 million m³

Weyburn Unit Overview

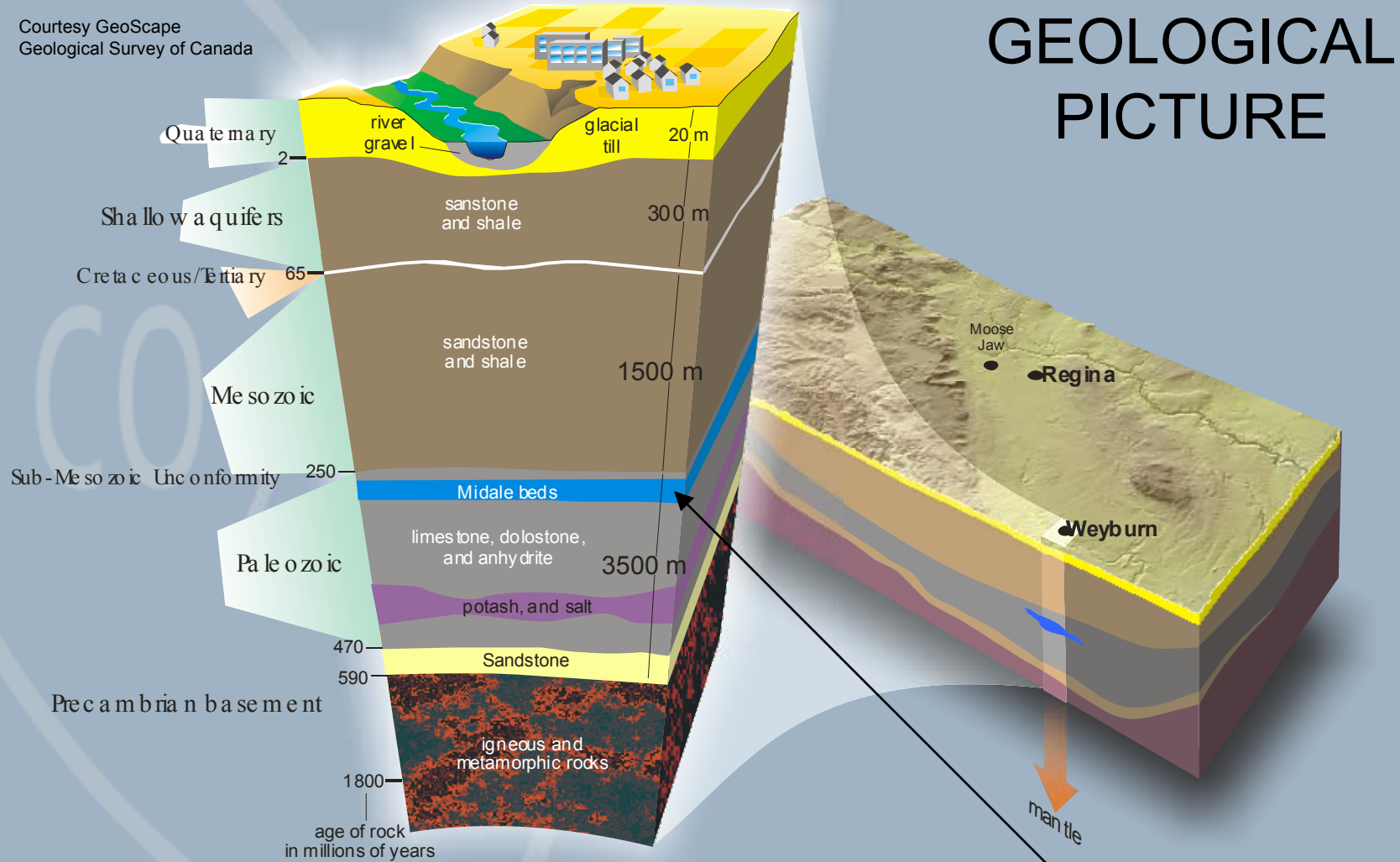


- EnCana: 62.1%
- Formation: Miss., Midale
- Depth: 1450m
- Discovered: 1954
- Current rate: 21,000 BOPD
- Wells: 946 total, 199 hz.
- Sour crude: 25 - 34 API
- OOIP: 1,400 MMbbls
- Cum. Prod. : 366 MMbbl (26%)



IEA Weyburn CO₂ Monitoring Project

Courtesy GeoScape
Geological Survey of Canada

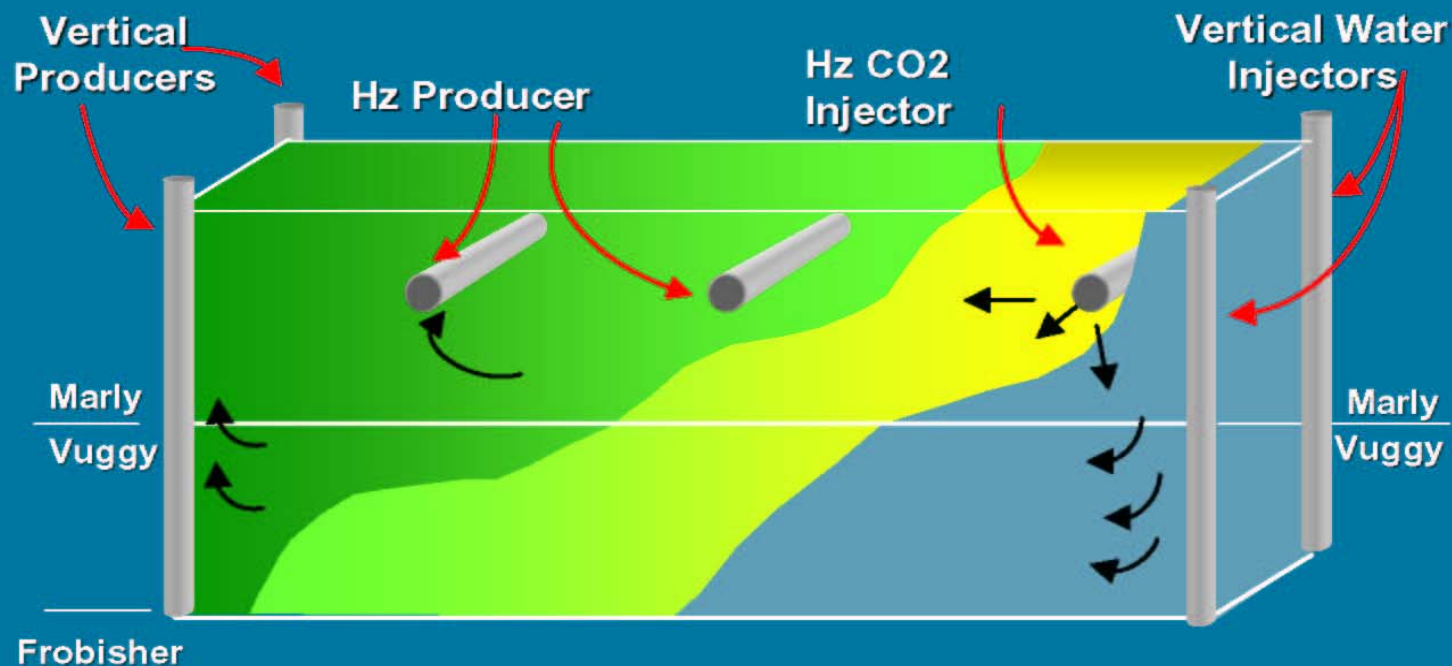


Geosphere: 150m below surface and deeper
Biosphere: 150m below surface (potable water limit) and above

The Weyburn reservoir: Marly and Vuggy zones

SSWG Operating Strategy

Quarter Pattern Section View

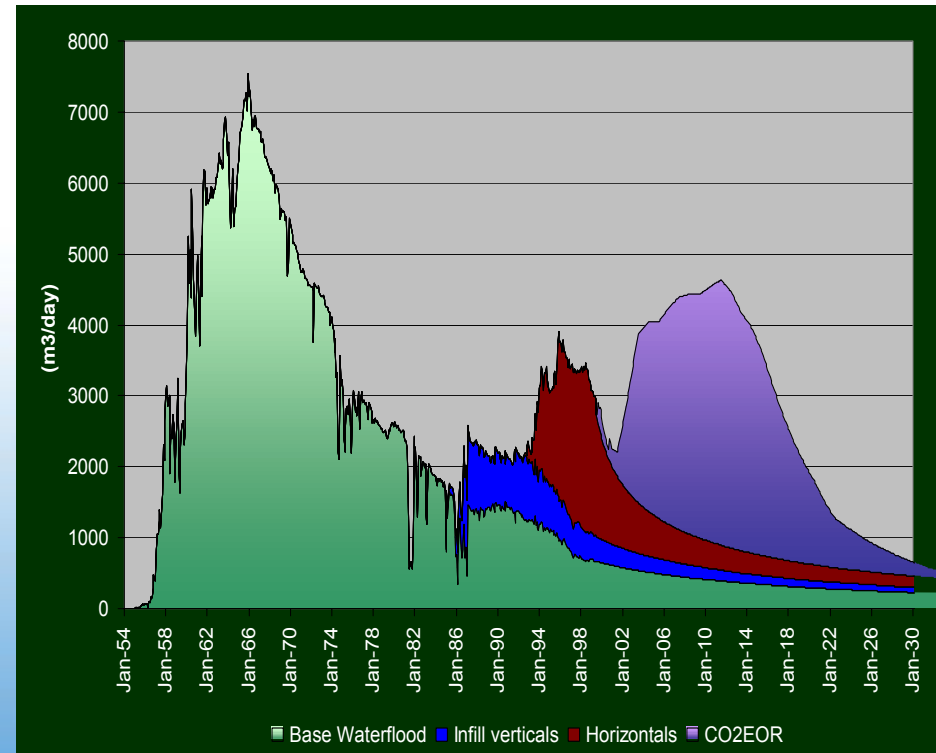


EnCana Operations



Update (Sept. 2000 – Dec. 2002)

- CO₂ injection into Phase 1A started Sept. 2000
- CO₂-EOR flood to 2025
- 14 M tons of CO₂ stored over 25 yrs
- Commercial project is rolling out beyond the Phase 1A monitoring project area
- Current CO₂ purchase: 3700 t/day
- 29% injected gas recycle
- 2.71 M tons injected to the end of Dec. 2002 (1.7 tons stored)
- 4.14 M tons injected to the end of Dec. 2003 (2.7 tons stored)
- Current incremental production: 4500 bbl/day (7.5m³/day) (~ 25% total)



Courtesy: EnCana Corporation



Natural Resources
Canada

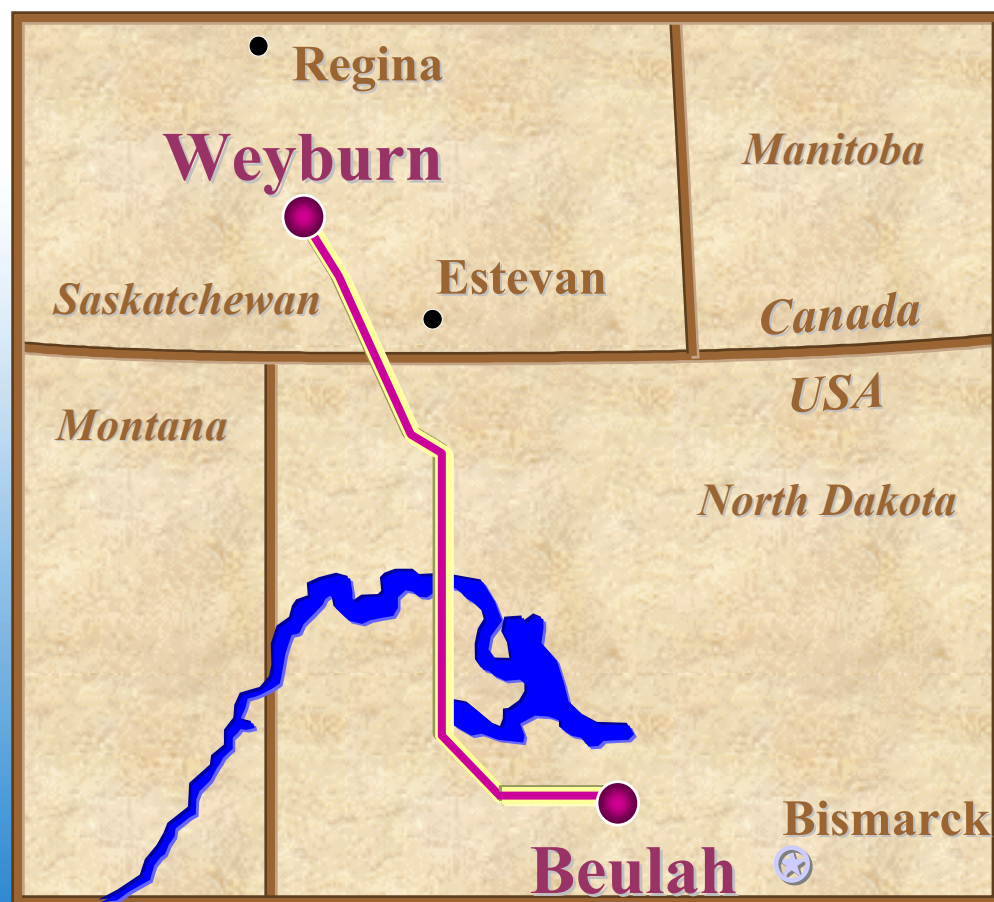
Ressources naturelles
Canada

Canada



The Source of CO₂

- **Dakota Gasification Company**
- **250 mmscfd (7.1million m³/day) CO₂ by-product of coal (lignite) gasification**
- **95 mmscfd (2.7million m³/day) contracted and injected at Weyburn (at Sept. 2000; injection rate declines as EOR production matures)**
- **CO₂ purity 95%**





2. IEA Weyburn Monitoring and Storage Project



Natural Resources
Canada

Ressources naturelles
Canada

Canada



IEA Weyburn CO₂ Monitoring and Storage Project

- **Mission**

- to assess the technical and economic feasibility of geological storage of CO₂ in oil reservoirs and develop implementation guidelines for such projects
- implicit in the assessment is the identification of the risks associated with this method of CO₂ storage, especially long-term risks of leakage





Rationale for Government Sponsorship

- Understanding CO₂ capture and geological storage is an important aspect of maintaining the fossil energy option in a carbon-constrained world
- We must demonstrate the economic benefits of CO₂ storage to ensure the option is viable
- This project will help ensure public acceptability of this important climate change option
- The results of this project will form part of the justification made by policy makers to exercise this climate change option





Rationale for Government Sponsorship (cont'd)

- **Weyburn presented a unique opportunity to monitor CO₂ geological storage from the onset of CO₂ flooding**
- **The CO₂ being used in this EOR project comes from the US and helps improve the economics of the Dakota Gasification Plant**
- **This project has the potential to represent the sustainable development goal: economically viable, environmentally responsible, and socially acceptable**
- **National and international public and private sector interests converge, giving us a rare opportunity to accomplish normally divergent goals**





Why Was The Weyburn Unit Selected?

- **World-class CO₂-enhanced oil recovery (EOR) project (CDN \$1.5 billion) (US \$1.1billion)**
- **Easily accessible site**
- **Substantial historical data base**
- **Extensively drilled with accurate records**
- **Pre-injection baseline data could be gathered**
- **Extremely supportive industrial partner (EnCana Corporation)**



A CO₂ injector site





Project Objectives

- Define the geoscience framework of the storage medium (the “geosphere”)
- Refine CO₂ movement predictions and verification techniques
- Identify the short- and long-term risks of CO₂ migration and leakage
- Improve storage capacity through improved reservoir conformance (CO₂ mobility control, various operating strategies)
- Define the economic limits of CO₂ geological storage



EnCana's Weyburn processing facilities



Project Sponsors

Governments:

- **Natural Resources Canada (NRCan)**
- **United States Department of Energy (US DOE)**
- **Saskatchewan Industry & Resources (SIR)**
- **Alberta Energy Research Institute (AERI)**
- **European Community (EU)**
- **International Energy Agency Greenhouse Gas R&D Programme (IEA GHG)**

Industry:

- **EnCana Corporation**
- **SaskPower**
- **Nexen Canada**
- **TotalFinaElf**
- **ChevronTexaco**
- **BP**
- **Dakota Gasification Co.**
- **TransAlta Utilities Corp.**
- **Engineering Advancement Association of Japan**





Research Providers

Canada:

- EnCana Corporation*
- Saskatchewan Industry & Resources*
- Saskatchewan Research Council
- University of Alberta
- University of Calgary
- University of Saskatchewan
- University of Regina
- J.D. Mollard and Associates Ltd.
- Alberta Research Council
- Geological Survey of Canada (NRCan)*
- Hampson Russell-Veritas
- Rakhit Petroleum Consulting
- Ecomatters Inc.
- Canadian Energy Research Institute

United States:

- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Colorado School of Mines
- Monitor Scientific LLC
- North Dakota Geological Survey

Europe:

- British Geological Survey (UK)*
- BRGM (France)*
- GEUS (Denmark)*
- ING (Italy)*
- Quintessa Ltd. (UK)





Project Management, Budget

- **Project Manager: Dr. Waleed Jazrawi, Petroleum Technology Research Centre, Regina, Saskatchewan**
- **Guided by Project Management Committee, 8 Task Managers**

- **Program budget**

- Field data collection	\$ 2.4 million Cdn\$
- Geology	\$ 2.1 million Cdn\$
- Geochemistry	\$ 4.3 million Cdn\$
- Monitoring CO ₂ movement	\$11.4 million Cdn\$
- Sequestration performance	<u>\$ 4.5 million Cdn\$</u>
	\$24.7 million Cdn\$
- “In kind” contribution	<u>\$17 million Cdn\$</u>
- Total	\$42 million Cdn\$ (\$28 million US\$)





Project Timing

- **Project started in September 2000**
- **Final report to be completed mid-2004**
- **Special session at September 2004 IEA GHG conference**
- **Planning for Phase II project underway**



Facility where main CO₂ pipeline enters Weyburn field from Beulah, ND





Project Scope

Principal Tasks:

- Field Performance Monitoring
- Geoscience Framework (Geosphere)
- Geochemical Monitoring & Modeling
- Caprock and Wellbore Integrity
- Seismic Tracking of CO₂
- Numerical Simulation of CO₂ Movement
- Long-Term CO₂ Fate Assessment
- CO₂ Storage Economic Model



**Vibroseis truck (seismic source)
used for 3-D seismic surveys**

*Note: Principal tasks are subdivided
into 31 distinct sub-tasks*





Monitoring CO₂ Movement

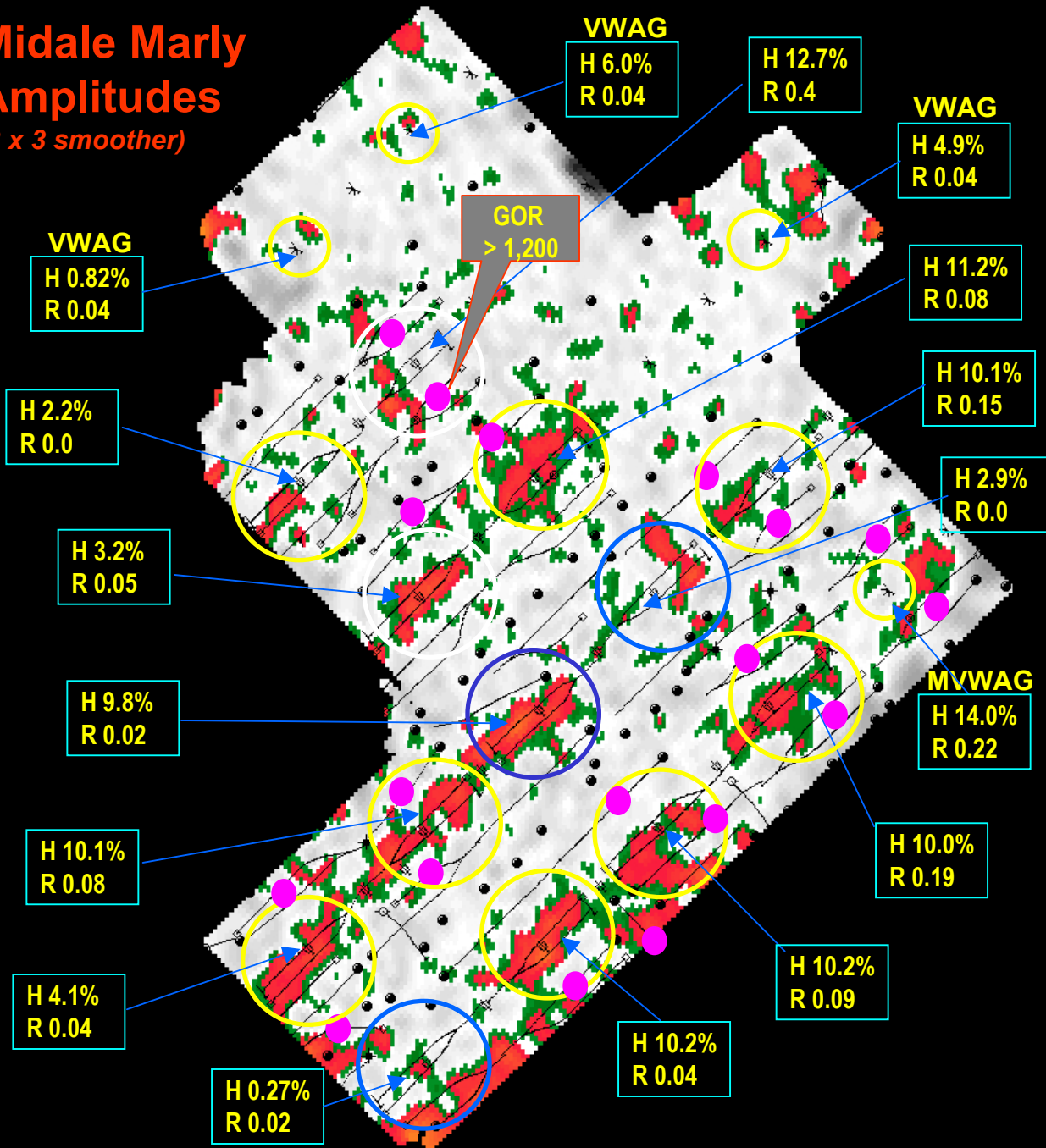


Production measurement and mixing facility

Techniques:

- 4D, 3C surface seismic
- 4D, 9C surface seismic
- 3D, 3C vertical seismic profile (VSP)
- Cross-well seismic (H and V wells)
- Passive micro-seismic
- Geochemical sampling analysis
- Tracer injection monitoring
- Conventional produced fluid analysis

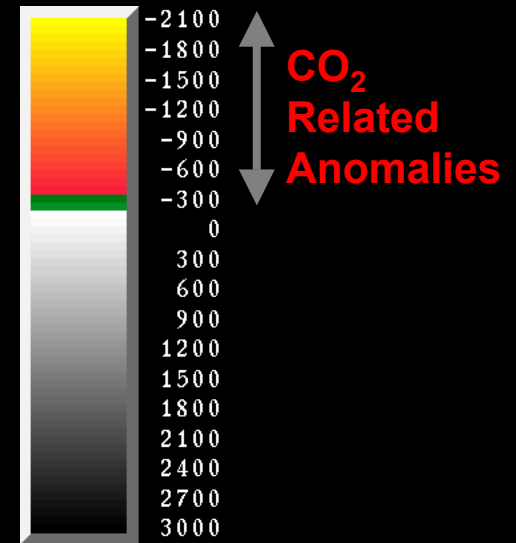
Midale Marly Amplitudes (3 x 3 smoother)



Seismic Detection of Weyburn Field CO₂ Miscible Flood

EnCana et al.
4-D P-Wave Data
(Bin Size 40 x 40 m)

Amp Scale



- H** - HCPV
- R** - Recycle ratio
- - Response well



Use of Computer Models to Predict CO₂ Movement

- **Computer models can be used to simulate what will happen when CO₂ is injected – sophisticated technique**
- **Models predict where CO₂ will go in the reservoir, rate of movement**
- **Results used by production engineers - help locate injection wells and production wells, avoid problems**
- **Early analyses are encouraging – good correspondence between prediction and field observations**
- **Lends confidence re predicting fate of injected CO₂**





Will the CO₂ Remain in the Weyburn Reservoir? “Storage Integrity”

- **Public confidence requires that objective information be available – critical issue for the understanding of the technology**
- **Key factors – vertical escape must be blocked by a tight overlying seal and closed reservoir**
- **Reservoir has held the oil over geological time, will it hold the CO₂?**
- **Risk of leakage around production wells, injection wells**

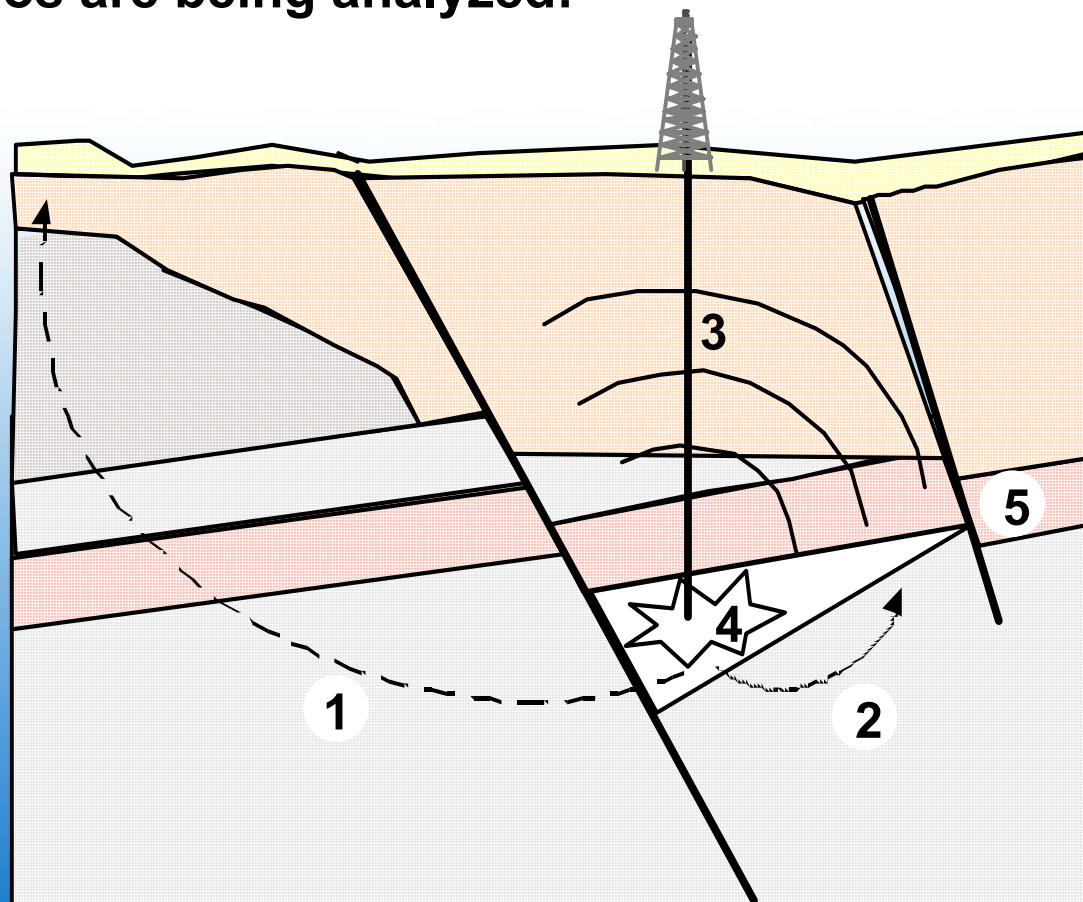




Risk Assessment of CO₂ Sequestration

A number of escape scenarios are being analyzed:

1. **Rapid “short-circuit” release (via fracture, borehole, or unconformity)**
2. **Potential long-term release**
3. **Induced seismic event**
4. **Disruption of host rock**
5. **Release to aquifer**





3. Weyburn's Contribution to Advancing CO₂ Storage





How Will Weyburn Help to Advance CO₂ Storage Technology?

Will yield several critical results:

- 1. Reliable estimates of net CO₂ stored in this reservoir, via production monitoring**
- 2. Follow movement of CO₂ in the reservoirs, using seismic monitoring, fluid recovery**
- 3. Evidence of possible chemical reactions between the CO₂ and reservoir fluids, using chemistry**
- 4. Advancements in monitoring techniques – seismic, computer simulation, geochemistry**
- 5. Increase database of information – for regulation, for studies which will inform public, build interest and confidence in CO₂ storage**





Issues Addressed by the Weyburn Monitoring Project

- **Public's level of comfort, acceptance* :**
 - Is CO₂ EOR for storage a safe practice?
 - Where does the CO₂ go after injection?
 - Will any CO₂ leak out, and if so where?
 - Will the CO₂ stay there over the long-term?
 - What will it mean to people and to the environment?
- * Very important to engage the public early, openly
- **Verification of quantities of CO₂ remaining in reservoir**
 - Quantifiable basis for emissions trading
- **Regulation increases regulator's experience and information base - safety, resource conservation, environment**





4. IEA Weyburn Monitoring Project

A Model for International Collaboration





International Collaboration at Weyburn - Features

- **Involves – EnCana, governments - Canada, Alberta, Saskatchewan, US DOE, EU, IEA, 9 companies, 24 research providers – 5 European, 5 US, 14 Canadian**
- **Built on a solid foundation provided by the IEA Greenhouse Gas R&D Program - expertise, ongoing engagement and collaboration**
- **High quality, sound scientific experiment – excellent baseline information, complementary disciplines brought to bear**
- **Widespread dissemination of information**
- **Field operator is strongly supportive, cooperative with the international monitoring project**





Concluding Remarks

- **Weyburn Oil Field – CO₂ EOR - a commercial and technical success**
- **Weyburn Monitoring Project – comprehensive package of the latest monitoring techniques, positive early results**
- **Addressing critical issues re public understanding, acceptance - assessment of CO₂ movement, leakage and verification**
- **Excellent team work, collaboration – IEA, private sector, universities, Canadian and international researchers**

“Weyburn – The World-Leading CO₂ Monitoring Project”

